Cooling Water Copper Pickup

- Concerns
- Calculating Copper Pickup
- Operating Plant Data

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1.) We're all concerned about the environment and the effect that copper release will have on aquatic life, but the bigger concern for you is probably compliance with copper limits set by Federal and State regulators under the National Pollutant Discharge Elimination System.

2.) Today, we are going to show you how to calculate copper pickup based on corrosion rate data and then,

3.) We are going to compare calculated levels of copper with actual data from operating plants.

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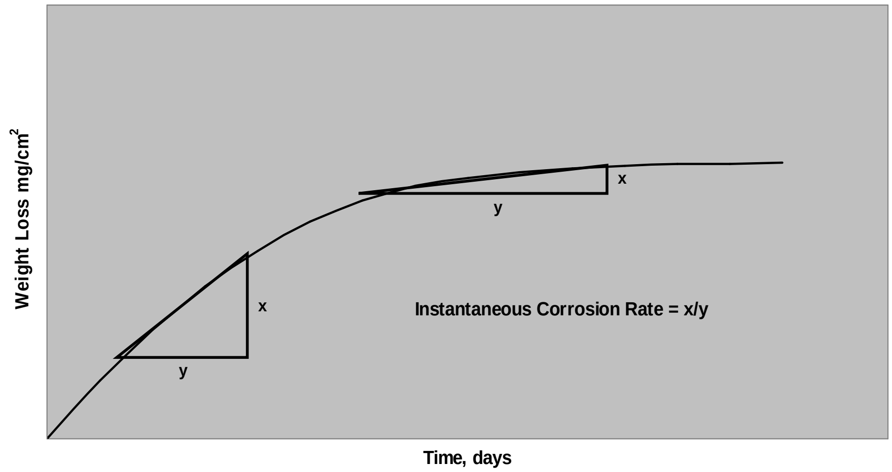
Weight Loss vs. Time Curves



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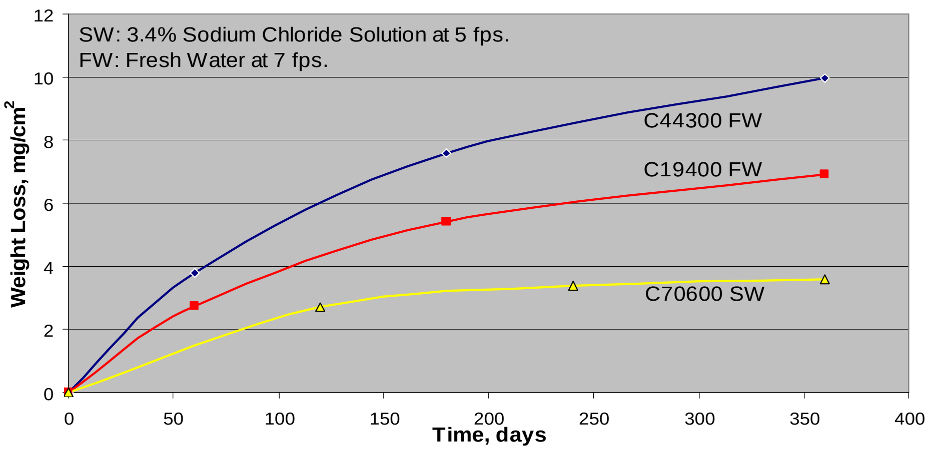
1.) Weight Loss versus Time Curves are useful for predicting long term results. but they are not good for predicting short term results. Let me explain.

2.) These curves are generated by immersing numerous samples in flowing water and then removing samples at various times. All samples are precisely weighed prior to being put into test. When they are removed, the corrosion products are removed (by scraping and brushing) and then the samples are cleaned in acid. The samples are then re-weighed and weight loss versus time is plotted.

3.) When the samples are first put into water, the corrosion product film (which gives the material its corrosion resistance) starts to form. 80% of the copper that appears as weight loss (in the short term samples) actually goes in to forming this corrosion product film, and is not released to the water. The corrosion product film takes about 3-6 months to fully form, and it has a limiting thickness. Thus, when the limiting thickness is been achieved, the corrosion rate curve flattens out, and the tangent at that point can be considered to be the steady state corrosion rate. Stated another way, when steady state is achieved, the copper that is measured as incremental weight loss can be considered as going in to the cooling water (since the film is no longer growing or getting thicker).

Weight Loss vs. Time Curves
Alloys C443, C194, and C706



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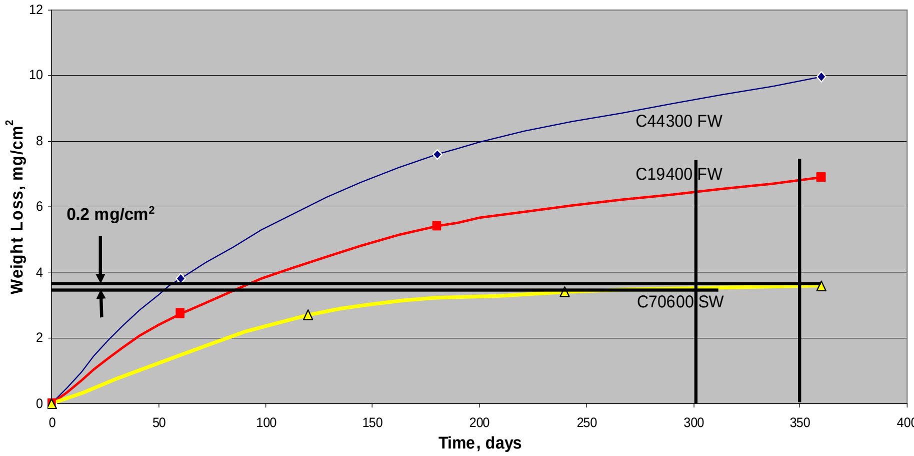
Here are the Weight Loss vs. Time Curves for three commonly used copper alloys – Admiralty Brass (C443), Iron-Modified Copper (C194), and 90/10 Copper-Nickel (C706). Let's do a calculation using the C706 curve.

C706 Weight Loss vs. Time Curve



$0.2 \text{ mg / cm}^2 / 50 \text{ days} = 2.8 \times 10^{-6} \text{ mg / cm}^2 / \text{min}$

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As can be seen, the steady state corrosion rate for C706 is 0.2 mg/sq.cm./50 days. This converts to 2.8 times 10 to the minus 6 mg per centimeter squared per minute. We make this conversion because power plant data for water flow through a condenser is often expressed as gallons per minute.

Example Calculations:
Once Through Cooling System

N – No. of tubes = 2020
L – Length = 20.187' = 242.244"
t – Wall Thickness = 0.049"
OD – Outside Diameter = 1"
ID – Inside Diameter = 0.902"
FR – Flow rate = 11,400 gpm
CR – C706 Corrosion Rate = 2.8×10^{-6} mg/cm^2/min
CF – mg into lb = 2.2046×10^{-6} lb/mg
ρ – Density of Water = 8.337 lb/gal
C – Portion of Cu in C706 = 90%

Internal Surface Area (SA):
$N*\pi*ID*L$ = 1,386,630 in^2 = 8,945,982 cm^2

Copper Discharged To Water (CDW):
$SA*CR*CF*C$ = 49.7×10^{-6} lb/min

Mass Flow Rate Water (MFW):
$FR*\rho$ = 95,042 lb/min

Copper Released = CDW/MFW = 0.52 ppb

Recirculating Cooling System: Same Calculations x Concentration Factor

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For our example calculation, we used the specs for a Boiler Feed Pump Turbine Drive Condenser; we picked such a condenser because we had the complete specs (we don't usually get complete specs with RFQ's that we receive).

As can be seen, there are 2020 tubes 1"OD x 0.049" Wall x 20.187 feet long with a water flow rate of 11,400 gpm. The inside diameter calculates to be 0.902" (we use this to calculate the internal surface area available for copper release) and we use the corrosion rate from the previous slide. Working through the numbers, we calculate the amount of copper released to the environment as 0.52 ppb. For a recirculating cooling system, we'd perform the same calculations and simply multiply the result by the design concentration factor.

Operating Plant Data

- ***Once-Through Systems*** **– Field test data for nine operating plants with once through systems indicated a 1 ppb average copper pickup – Compton and Corcoran, "The Discharge of Copper Corrosion Products from Steam Electric and Desalination Plants and its Effect on the Nearby Ecosystem", INCRA Final Report, June 1, 1974 and Electrical World, January 15, 1976.**

- ***Recirculating Cooling Systems*** **–**
  - **Two 1300 MW plants surveyed**
  - **Alloy C194 Condenser Tube**
  - **Plant 1 after 2 years of service – 6.4 ppb discharge less 1.8 ppb incoming = 4.6 ppb copper pickup**
  - **Plant 2 after 1 year in service – less than 1 ppb in discharge water**

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Cooling Water Copper Pickup Summary

- **Long term (steady-state) copper pickup is negligible in properly designed and properly operated condensers.**
- **90/10 Copper-Nickel exhibits the lowest general corrosion rate of all commonly used copper alloys and should therefore exhibit the lowest copper release rates.**
- **Initial (Start-Up) release rates are higher than steady state rates but within acceptable limits.**
- **Only soluble ionic forms of copper are actually toxic to aquatic life; ionic copper represent about 25% of total dissolved copper.**

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